

HL 2-1985-557

# **EXECUTIVE SUMMARY**

**TWIN BUTTE  
SOILS AND WATER EVALUATION  
TASK FORCE**

**AUGUST, 1984**

ON 533-1905



August 3, 1984

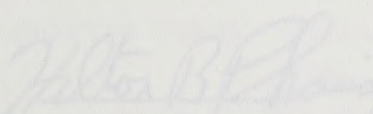
HON. FRED BRADLEY  
Minister of the Environment  
Legislative Buildings  
Edmonton, Alberta

**EXECUTIVE SUMMARY**

Mr. Minister:

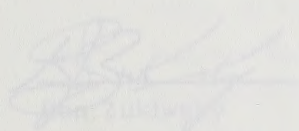
We take pleasure in submitting the EXECUTIVE SUMMARY of the  
TWIN BUTTE SOILS & WATER EVALUATION TASK FORCE.  
We have also attached a TECHNICAL REPORT and the Technical  
appendices to this report in separate volumes for future  
reference.

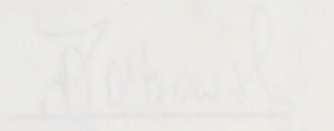
Respectfully,

  
Helen R. Pharis  
Chairman

  
Dr. Eric Tolstikhin

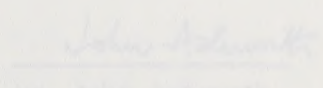
**TWIN BUTTE  
SOILS AND WATER EVALUATION**

  
Dr. Tadewasz Zabrowski

  
Dr. Tadewasz Zabrowski

**TASK FORCE**

  
John Ashworth

  
Dr. John Ashworth

  
Wendy Carpentier

**AUGUST, 1984**



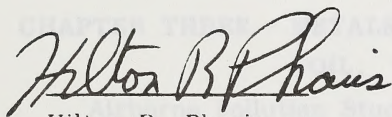
August 3, 1984

HON. FRED BRADLEY  
Minister of the Environment  
Legislative Buildings  
Edmonton, Alberta

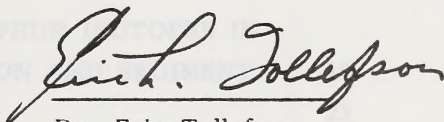
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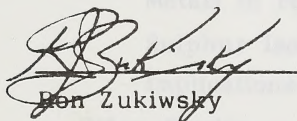
Respectfully,



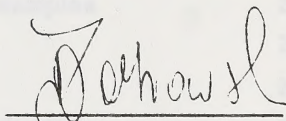
Hilton R. Pharis,  
Chairman



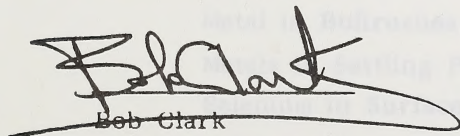
Dr. Eric Tollefson



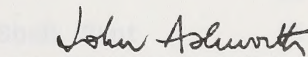
Ben Zukiwsky



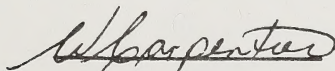
Dr. Tadeusz Dabrowski



Bob Clark



Dr. John Ashworth



Wendy Carpentier

HON. FRANK BRADLEY  
Minister of the Environment  
Legislative Buildings  
Edmonton, Alberta

Mr. Minister,

We take pleasure in submitting the EXECUTIVE SUMMARY of the  
TWIN TOWER WATER EVALUATION TASK FORCE.  
We have also attached a TECHNICAL REPORT and the Technical  
Appendix to this report in separate volumes for your  
reference.

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Dr. Eric Toivonen

William H. Smith

Chairman

Dr. Eric Toivonen

Dr. William H. Smith

Dr. John Ashworth

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CHAPTER ONE

## INTRODUCTION

The Twin Butte Site and Water Evaluation Task Force was appointed by Ministerial Order of the Hon. Fred Soudy, Minister of Environment on April 22, 1983. The Task Force was made up of the following members:

- Mr. Hilton Pharis, Chairman;

A rancher and Reeve of the Municipal District of  
Packer Creek.

- Mr. Ron Zukowsky;

School Principal - ii - Packer Creek Town councillor.

- Mr. Bob Clark;



## **CHAPTER ONE**

### **INTRODUCTION**

The Twin Butte Soils and Water Evaluation Task Force was appointed by Ministerial Order of the Hon. Fred Bradley, Minister of Environment on April 28, 1983. The Task Force was made up of the following members:

- Mr. Hilton Pharis, Chairman;  
A rancher and Reeve of the Municipal District of Pincher Creek.
- Mr. Ron Zukiwsky;  
School Principal and Pincher Creek Town councillor.
- Mr. Bob Clark;  
Former member of the Legislature for Olds-Didsbury.



- Mrs. Wendy Carpentier;  
An area resident and President of the Pincher Creek Industrial Pollution Committee.
  
- Dr. Eric Tollefson;  
Professor of Chemical Engineering, University of Calgary.
  
- Dr. Tadeusz Dabrowski;  
A Calgary hydrogeologist with the firm of Piteau and Associates.
  
- Dr. John Ashworth;  
A soil chemist with Norwest Soil Research Ltd. in Edmonton.

The Terms of Reference of the Task Force as outlined by the Minister of Environment were:

1. determine the nature and level of substances which are contained on the Gulf Pincher Creek and Shell Waterton gas plant sites resulting from the gas plant operations;
2. determine if any surface or sub-surface migration of these substances off of the plant site areas has occurred and the extent thereof.

The Task Force was also directed to conduct an independent study to evaluate the Gulf Canada report which identified heavy metals and organic compounds on the Gulf site.



The study area included:

- the populated areas immediately surrounding the Shell Waterton and Gulf Pincher Creek Plants
- the rural areas of Glenwood, Hill Spring and Twin Butte.

The objectives of the Task Force were established through a series of meetings with concerned citizens, visits to the plant sites and reviews of the existing reports regarding the soil and water on both plant sites. Following this process, the committee developed and conducted a research program that met the Terms of Reference set out for the Task Force.

Surface migration was discussed at length by the committee and taken to include the gaseous particulate emissions leaving the incinerator and flare stacks of the plants as well as particulate and gaseous matter carried by the wind from above the plant site. The Minister of Environment was advised and agreed with the intentions of the Task Force to include this concern in its mandate.

The Task Force outlined a program to be conducted by consulting and research organizations, coordinated its execution and evaluated the results. This program included:

- Hydrochemical Study of the Twin Butte area by Alberta Research Council.
- Source and Ambient Air Evaluation Study for the Twin Butte area by the Kananaskis Centre for Environmental Research.



- Pincher Creek Trace Element Study by Hardy Associates (1978) Ltd.

Several analytical projects of a less extensive nature designed to determine the quality of specific aspects of soil, air and water were undertaken by:

Saskatchewan Research Council

Chemex

University of Calgary, Physics Department

University of Windsor, Chemical Engineering  
Department

Metro Tech Systems Ltd.

Alberta Research Council

Chemical and Geological Lab

Others

The work of the Task Force is documented in this Executive Summary, a more detailed Technical Report and three separate volumes of Technical Appendices. These documents were prepared by the Task Force Members and were then reviewed and approved by the Task Force as a whole before publication. The Task Force expresses its appreciation to Executive Suite Business Centres Ltd. for editorial and word processing assistance provided during the preparation of the several draft and final documents.



## **CHAPTER TWO**

### **SURFACE WATER AND GROUNDWATER HYDROLOGY**

The purpose of this aspect of the study was to determine the potential of surface water and groundwater contamination due to sour gas plant operations in the Twin Butte area.

The reconnaissance field program completed by Monenco in November 1982 at the Gulf Canada Resources Inc., Pincher Creek plant identified several toxic metals in high concentrations in wastewater and surface runoff collection ponds and high levels of sulphates in groundwater in the sulphur block area. The results of this study raised the concerns of the local residents regarding potential health



hazards related to the potential surface and groundwater contamination resulting from the plant operation.

Five potential sources of surface water and groundwater contamination were considered by the Task Force. These were:

- accidental spills of contaminants on the sites,
- seepage from process basins and surface runoff ponds,
- leachate movement from the landfill sites,
- effluent disposal,
- precipitation of gaseous emissions from the incinerator and flare stacks and sulphur dust deposition on the ground surface.

It was also recognized that organic compounds from the incinerator and flare stacks could contribute to water contamination. Rather than analyzing each water sample for hundreds of possible organic components, it was decided to conduct a survey of components leaving the plants via the air mass. Since that survey identifies that there were organic compounds of concern in the air, an additional water sampling program is being recommended.

The study area is located within the eastern flank of the Rocky Mountain Foothills. Ground surface elevations in the Twin Butte and Hill Spring area range from approximately 1500 m above sea level at the Shell Waterton Gas Plant area to approximately 1180 m above sea level at the Waterton Reservoir.

The area has a well-developed surface drainage system, represented by a number of creeks, which belong to the Waterton River drainage basin.



The climatic conditions in the Twin Butte area may be classified as humid continental. The mean annual precipitation ranges from 508 mm in the northwestern part to 815 mm in the southwestern part of the area. Potential evapotranspiration is relatively high and may be in the order of 400 mm. The mean annual temperature is approximately 4°C.

The geological conditions in the Twin Butte area are highly variable. The Quaternary deposits overlying the bedrock formations consist of glacial, alluvial, glaciofluvial and lacustrine deposits with total thicknesses ranging from less than 1 m to over 50 m.

The bedrock in the area is represented mostly by shales and sandstones representing different formations of the Cretaceous age. The structural conditions are very complex due to a number of major faults intersecting the region.

#### **SURFACE WATER QUALITY**

A number of chemical and biological surveys were conducted in the period 1971 - 1983 to assess the potential impact of the Shell and Gulf gas plant operations on surface water quality in the Twin Butte area. The results of the studies indicate some changes in the water quality of North Drywood Creek and Drywood Creek, which might be attributed to plant effluent. Other creeks in the Waterton River watershed appear not to have been affected by the plant operations.



## Shell Waterton Gas Plant

A discharge of slightly brackish Shell Plant effluent with total dissolved solids ranging from 1334 to 3594 mg/L has increased the amount of dissolved matter in the North Drywood Creek to a maximum measured level of 1357 mg/L (83.02.09) below the effluent discharge point. Further downstream at the highway #6 crossing, the TDS ranged from 210 to 818 mg/L. The background level of total dissolved solids measured in the creek was 229 to 349 mg/L.

An increase in calcium, sodium, sulphate and chloride concentrations is observed immediately below the Shell Plant effluent discharge point. The concentration of these ions decreases gradually due to dilution downstream. The plant also introduces nutrients to the North Drywood Creek. Above the discharge point, concentrations of ammonia and phosphate are below the detection limits (for both compounds - 0.1 mg/L) while below the discharge point, their concentrations vary as follows:

- ammonia - below detection limit to 0.3 mg/L
- phosphate - 0.2 to 2.3 mg/L.

The presence of nutrients encourages algal growth in the stream water.

The increase in trace element concentrations in the North Drywood Creek is difficult to define since in many instances, concentrations of these elements in the effluent are very low. According to the available chemical analyses, an increase in the following trace



element concentrations was observed below the Shell Plant discharge point. These are: arsenic, boron, selenium, zinc, lead and nickel, with only selenium and arsenic exceeding the maximum acceptable concentrations for drinking water. Further downstream, at the Highway #6 crossing, concentrations of both selenium and arsenic were always below the maximum acceptable for drinking water.

High concentrations of arsenic in the Shell Plant effluent were traced to the gas well Waterton #42. To avoid surface water contamination in the future, formation water from the Sheet IV wells is injected into a deep disposal well.

Very small quantities of cyanide (0.05 to 0.07 mg/L) were observed in the plant effluent in the spring of 1983. The cyanide concentration rose from less than the detection limit (0.01 mg/L) upstream from the plant to 0.02 mg/L in the stream below the discharge point. This value is approximately one tenth of the maximum acceptable concentration for drinking water.

### **Gulf Pincher Creek Gas Plant**

The study conducted by Monenco Consultants Ltd. at Gulf's Pincher Creek Gas Plant (1983) indicates the presence of brackish water in some ponds. Dominant ions are calcium, magnesium, sodium and sulphate with the last reaching concentrations in the order of 4,000 mg/L in the sulphur block runoff pond (Pond 8). The ammonia-nitrogen concentrations in Pond 9 substantially exceed background levels.



Samples taken by Monenco from the ponds for trace element analyses were not filtered. Since the tests were intended to determine levels of dissolved rather than suspended matter, the results may not be representative.

In the sulphur block runoff pond, where water is highly acidic (pH = 2.2), concentrations of all tested trace elements, with the exception of barium, substantially exceeded the background levels. Similar results were obtained from the lake located southwest of the solid waste disposal pit. Other reservoirs (Ponds 6, 7, Pond 6 weir and Pond 9) contained water with iron, manganese and chromium concentrations higher than observed in the control samples.

The highest cyanide concentrations were observed in Ponds 6 and 9 and the surface drainage channel south of the landfill area (maximum - 0.001 mg/L). Even such a low concentration appears to be slightly higher than those observed in surface water samples collected in the adjacent areas.

The hydrocarbon concentrations measured on-site are similar to those observed in the off-site water samples.

During the course of the Monenco study (1983), no water from the retention ponds was discharged to the surface drainage system. Therefore no data on water quality in the Drywood Creek below the discharge point is available.



## GROUNDWATER QUALITY

The groundwater quality depends on many factors; climatic conditions, type of deposits in which groundwater is present, and circulation conditions. Since most of the wells tested in the area are relatively shallow (less than 100 m deep) it was assumed that the samples represent groundwater occurring within a zone of active water exchange. This assumption was later confirmed by the environmental isotope study. A lack of geological logs for most of the wells makes it impossible to differentiate between samples collected from Quaternary and Cretaceous deposits. Most of the wells were completed in Quaternary deposits, with only a few reaching the bedrock.

The water yielding characteristic of Quaternary sediments depends on the thickness of the deposit, hydraulic conductivity, lateral extent, terrain topography and recharge conditions. The hydraulic properties of these deposits vary from medium hydraulic conductivity silty sands and gravels to low hydraulic conductivity till and clay deposits. The presence of different types of deposits affects the groundwater recharge and circulation conditions. These variable conditions contribute to the presence of different hydrochemical types of groundwater in the study area.

The majority of groundwater samples represent the calcium-magnesium-bicarbonate type. Less common are the calcium-magnesium-sulphate, sodium-sulphate and sodium-bicarbonate-sulphate types. The total dissolved solids range from approximately 300 to 5,000 mg/L. Groundwater has a slightly alkaline character with pH varying between 7.0 to 9.6.



Groundwater with high TDS usually has high  $\text{SO}_4$  content, which may exceed 3,500 mg/L (maximum acceptable for drinking water is 500 mg/L). Chloride concentrations in groundwaters present in the study area are very low.

Nitrate concentrations in many shallow wells and springs are very high, reaching 156 mg/L (as N). Domestic sewage and seepage from barnyards are common sources of nitrates in the groundwater in the rural areas. Other sources of nitrates may be fertilizers and industrial plant effluents. According to the information obtained from the local residents, use of fertilizers in the study area is very limited. The concentration of nitrates in the Shell Plant effluent is usually low and does not exceed 10 mg/L.

Hendry et al. (1984) determined that the high nitrates found below groundwater surface in the weathered till are the result of the oxidation of ammonium present within the tills. Nitrate concentrations in groundwater samples collected in southern Alberta may exceed 300 mg/L.

Iron and manganese are very common constituents of groundwater in the study area with maximum concentrations of 20 mg/L and 1 mg/L respectively. These values exceed maximum acceptable concentrations for drinking water, which are 0.3 mg/L for iron and 0.05 mg/L for manganese.

Other trace elements (eg. mercury, cadmium, chromium, lead, arsenic) were found in groundwater at concentrations that in general did not exceed Canadian Drinking Water Standards.



Higher concentrations of toxic metals such as lead, chromium and cadmium, were detected in groundwater samples on isolated occasions in different wells. Some of the wells were sampled several times with only one analysis indicating anomalously high concentrations of a particular element. These anomalies may be attributed either to erroneous analyses or improper sampling techniques which led to sample contamination.

The distribution of trace elements in groundwater collected in the area adjacent to the Shell and Gulf gas plants does not indicate any sign of industrial pollution.

#### **Shell Waterton Gas Plant**

The knowledge of hydrogeological conditions at the Shell Waterton gas plant is limited. Therefore, it is not possible to define the existence and extent of potential groundwater contamination zones within the plant area.

Terrain topography (largely flat areas) and the presence of permeable deposits (gravel, sand and silt) on the ground surface indicate the potential for groundwater contamination as a result of accidental spillage of chemicals or seepage from the retention ponds. Installed piezometers appear to indicate certain groundwater contamination in the plant area which is expressed by variable main ion composition, higher TDS, elevated levels of nitrate/nitrite, high iron, manganese and local chromium concentrations. These parameters are different from those observed in springs and seeps not affected by the plant operation.



A review of the available geological and hydrogeological information indicates that the groundwater flow from the majority of the Shell plant area is directed toward the North Drywood Creek Valley. Localized areas may be also drained towards the north and east of the plant. The quality of water in a spring located south of the plant in the North Drywood Creek Valley (Spring No. 1) has been affected by seepage from the sulphur block surface run-off pond. It exhibits very high sulphate concentrations (over 1,000 mg/L) and higher concentrations of main ions in comparison with other springs and seeps monitored.

Groundwater in four nests of piezometers located immediately north and east of the processing facilities and ponds at the Shell plant was contaminated with sulpholane (a chemical used in the sour gas treatment process) in concentrations up to 100 ppm. A natural water seep 1 km west of the plant reservoir contained no sulpholane.

Sulpholane is essentially non-toxic, but its use as a solubilizing agent in the plant process suggests that other, potentially more toxic compounds might enter groundwater in conjunction with it.

Only low concentrations of other organic compounds were detected in groundwater samples taken in June 1984. A more extensive set of piezometer nests should be installed to permit monitoring of groundwater at the Shell plant in future. This should make it possible to monitor sulpholane and associated compounds, and to delineate the extent of contaminated groundwater zones.



## **Gulf Pincher Creek Gas Plant**

The Gulf Pincher Creek Gas Plant is situated in an area where a thick layer (30 to 42 m) of silty clay till of low hydraulic conductivity overlies the older sediments. In this area, movement of contaminants would be relatively slow and, in most cases, restricted to the upper water bearing zone. Higher hydraulic conductivity lenses (more silty or gravelly layers) were found throughout the till. It is believed that these layers are discontinuous and are not hydraulically connected.

The areas of groundwater contamination due to plant activities and seepage from the ponds within the Gulf property are delineated in the Monenco Reports #5 and #6. The available data indicate that the zones of contaminated water are localized within the plant boundaries. The only exception is an area located southeast of Pond 8, where higher sulphate and total dissolved solids concentrations were observed over 100 m beyond the plant limits within the upper aquifer. In the same area, a piezometer (29-1) installed within the preglacial gravel deposits underlying the till deposits (lower aquifer) indicates the presence of groundwater with raised total dissolved solids and sulphate concentrations. The origin of these anomalies should be investigated further by Gulf to determine the source of anomalous sulphate concentrations. If the anomalies in both aquifers are related to the plant operation, it would indicate that in the general area of Pond 8, a hydrogeological window exists, which allows groundwater movement from the upper aquifer through the till into the lower aquifer.



All existing data on organic chemicals in groundwater on or near the Gulf plant site were summarized in a memorandum from Monenco Consultants Ltd. to Gulf Resources Ltd., appended to the Technical Report of this Task Force (Appendix H-2).

Groundwater at the Gulf plant was severely contaminated directly beneath a waste pit used for unflared residues for many years; fortunately, this contamination is centrally located on the site. Samples taken from the site periphery or off-site had little or no contamination with organic material.

During the past exploration programs, a number of piezometers were installed in the plant area. The existing groundwater observation network will be supplemented by Gulf with additional piezometers in the future. Selected piezometers will be utilized as permanent groundwater monitoring points.

## **CHEMICAL WEATHERING POTENTIAL**

The purpose of this laboratory experiment conducted by Dr. E. I. Wallick (Alberta Research Council) was to define the potential for release of toxic heavy metals from local till material in an SO<sub>2</sub> enriched atmosphere. If the release of heavy metals from till were found to occur at SO<sub>2</sub> concentrations much higher than those present in the vicinity of the sour gas plants, the position could be taken that given sufficient time, the metals would be leached at much lower concentrations of SO<sub>2</sub> in the air.



The weathering experiments were conducted on six till samples over 16 days in a control and in a variable atmosphere chamber. Only one sample showed a noticeable drop in pH (2.4) under an atmosphere containing a partial pressure of  $\text{SO}_2$  corresponding to a concentration of 0.34 percent (3400 mg/L). This indicates a lower buffering capacity of this particular sample till. The drop in pH was associated with an increase in concentrations of trace metals. The trace metals released were not at a toxic level, as defined in "Guidelines for Canadian Drinking Water Quality", even at a pH as low as 2.4. The obtained results indicate that the release of trace metals may conceivably occur at very high concentrations of  $\text{SO}_2$ . The remaining five samples showed a decrease of pH from approximately 9 to 7. At this pH level, no increase in trace element concentrations could be observed.

Gaseous emissions from the incinerator stack are dispersed into the atmosphere, creating low concentrations of  $\text{SO}_2$ . Concentrations of  $\text{SO}_2$  in the weathering chamber were several hundred times higher than the  $\text{SO}_2$  concentrations observed in the air in the plant vicinity (in the order of 0.02 mg/L). Making simplifying assumptions, a one-day test at an  $\text{SO}_2$  concentration of 34 mg/L may be considered as an equivalent to 1700 days (approximately 4.6 years) under field conditions. For higher  $\text{SO}_2$  concentrations (3400 mg/L), a one-day test would be the equivalent of 465 years. Based on these tests, there is no reason to believe the release of  $\text{SO}_2$  has had or will have an adverse affect on groundwater quality.

The most important observations based upon the analysis of six till samples from the Twin Butte area are that a



threshold partial pressure exists below which there is little or no reaction of  $\text{SO}_2$  with an aqueous suspension of soil/till, and that the release of trace metals can occur only if the pH of the soil water system falls to 3.0 approximately. The threshold value of the partial pressure of  $\text{SO}_2$  corresponds to a concentration of between 34 mg/L and 3400 mg/L for the materials studied. Increasing amounts of organic carbon, calcium, sulfate, silica, copper, lead, cadmium, cobalt, nickel, manganese, vanadium, chromium, strontium, aluminium, and zinc were released upon exposure of a shallow till sample to 0.34 percent  $\text{SO}_2$ .



### **CHAPTER THREE**

#### **METALS AND SULPHUR ISOTOPES IN SOIL VEGETATION & SEDIMENT**

Soon after the Task Force was commissioned, reports on studies of possible metal emissions from the Gulf and Shell gas plants were released which attracted much publicity, in particular the report by Snider (1983).

The evidence in these reports was conflicting and the members of the Task Force decided that further work was necessary in order to establish whether or not significant amounts of potentially toxic air-borne metals have been deposited in the area near the gas plants during their years of operation.



In order to accomplish this objective, soil, leaf litter, grass and lake sediment samples were taken from sites beside lakes (referred to below as "lakeside samples") at various distances up to 15 km from the gas plants. These samples were analyzed for the following suite of metals: arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se) and zinc (Zn). Soil, litter and sediment samples were also analyzed for pH and electrical conductivity.

In addition to these measurements, garden vegetables were obtained from residents at various distances up to 15 km from the gas plants and also analyzed. These vegetables were taken in response to the suggestion that by eating home-grown vegetables, residents of the area might unwittingly be ingesting large quantities of some metals.

The soil, litter, grass, lake sediment and garden vegetable samples were also analyzed for  $^{34}\text{S}$ : $^{32}\text{S}$  ratios. In the samples analyzed, this measurement indicates the relative proportions of sour gas sulphur (rich in  $^{34}\text{S}$ , the heavier stable isotope of sulphur) and sulphur derived from natural sources, which is richer in  $^{32}\text{S}$ .

Bullrush samples were taken downslope from the settling ponds at both the Shell and Gulf plants and from three ponds at the Gulf plant.

Sediment samples and water from settling ponds at the Shell plant were collected and analyzed. These measurements were undertaken in keeping with the terms of reference of the Task Force, in particular the requirement to investigate the possibility of sub-surface migration of toxic substances from the gas plant sites.



## AIRBORNE POLLUTION STUDIES

This section summarizes the analysis of "lakeside" samples and home-grown vegetables for metals and sulphur isotopes.

### Metals in "Lakeside" Samples

The results of analyzing the grass, litter, topsoil and sediment samples from near the various lakes are given in full in the report by Hardy Associates appended to the main report (Appendix S-1).

A comparison of the results with average metal concentrations in soil and grass indicates that "lake-side" grass generally contained smaller concentrations of metals than are normally found in grass. Concentrations of metals in the corresponding soil samples were within a factor of 2 or 3, compared to those normally found in soil.

More important than the absence of any abnormally large metal concentration, for present purposes, is the absence of any trend in the results with either point of origin, or proximity to the sour gas plants. This finding refutes the suggestion that any substantial deposition of the metals analyzed for has occurred as a result of aerial transport from the sites of sour gas processing operations.

Equally, there were no trends in pH and electrical conductivity of topsoil, litter and lake sediment that might indicate contamination due to gas plant operations.



## Sulphur Isotopes in "Lakeside" Samples

Results of measuring  $\delta^{34}\text{S}$  values (the ratio of  $^{34}\text{S}$  to the more common  $^{32}\text{S}$ , expressed in parts per thousand) in elemental sulphur from the sulphur block at the Gulf plant; from untreated sour gas from the Gulf plant and from the two separate "sheets" processed by the Shell plant; and from atmospheric samples of particulate material and of air filters exposed for approximately one day downwind from the Shell plant show that windblown elemental sulphur and other forms of air-borne sulphur from the gas plants have strongly positive  $\delta^{34}\text{S}$  values in the range 16-25.

In general, the values found in soil samples ranged from around zero to minus 5 in samples taken from sites near the Drywood Creek valley which connects the Shell and Gulf plants, and fell to more negative values at sites further away, with the most negative value being found at Marna Lake, 16 km northwest of the Shell plant.

Values of  $\delta^{34}\text{S}$  found in grass and especially in surface litter samples were much more positive, and most lake sediment values much more negative than those for soil. The relative values for grass and for the A horizon of soil at a site may be the best indicator of sulphur deposition there due to gas plant operation.

These relative values indicate a zone of intensive  $^{34}\text{S}$  deposition in the direction of the Drywood Creek valley at least as far east as the Waterton Reservoir, another zone in the direction of the Pincher Creek valley at least as far north as Daigle Lake, and possibly another zone in the direction of the valley of Foothill Creek as far as Rouleau Lake.



## **Metals in Potatoes and Carrots**

The potatoes and carrots submitted by residents were also analyzed; the results indicate that eating ordinary servings of these vegetables would supply only a portion of the average daily intake of the elements normally contained in food.

There were no trends in the results when viewed in relation to the source of the samples.

The implications of these results are that there is no sign that sour gas processing operations have affected concentrations of any element analyzed for, and that the vegetables sampled would not provide a dangerously large amount of any of these elements, when included in the diet.

## **Sulphur Isotopes in Vegetables**

The  $\delta^{34}\text{S}$  values for the potatoes and carrots submitted by local residents to Mr. Bob Lyons, the District Agriculturist, generally followed the trend described above. The most positive values were observed, for the most part, at sites near the valley of Drywood Creek.

## **Implications of Sulphur Isotope Studies**

Since any pollution by metals emitted from the gas plants would follow a similar trend to that observed for air-borne sulphur it follows that, in the absence of any discernible trend in concentrations of metals with distance and orientation of the sampling sites from the gas plants, the amounts of these metals are insignificant compared with amounts present naturally.



## **OTHER STUDIES**

This section of the report summarizes the analysis for metals and sulphur isotopes in bullrushes, metals in the settling ponds of the Shell Waterton plant and selenium in topsoil at the Gulf Pincher Creek plant.

### **Metals in Bullrushes**

Bullrushes downslope from the Shell plant had metal concentrations in tops and roots similar to or smaller than those found in bullrushes taken from lakes up to 15 km away. However, some bullrushes from ponds at the Gulf plant, and downslope from the Gulf plant, had high concentrations of chromium, lead and zinc relative to those in the control samples.

The results are consistent with contamination of parts of the area downslope from the settling ponds at the Gulf plant having occurred due to surface run-off. This contamination is not seen as a serious hazard, but supports the suggestion made earlier under Groundwater Quality in Chapter Two that the area south-east of the settling ponds at the Gulf plant continue to be monitored in future.

### **Metals in Settling Ponds at the Shell Plant**

The results of analyzing nine settling ponds at the Shell plant show that sediment samples from those ponds contained concentrations of metals higher than those found in lake sediments by a factor of approximately 2 generally and, in some instances, by a factor of approximately 5.



This finding is not surprising given the function of the settling ponds. Concentrations of cadmium, mercury and zinc were similar to those reported by Monenco Ltd. in their preliminary estimate of pond sludge residues at the Gulf plant. Concentrations of chromium were much less in the Shell plant sediment than at the Gulf plant, due presumably to the absence of chromium compounds from the Shell processing treatment.

It has already been pointed out in Chapter Two of this executive summary, that there is no sign that metals from the settling ponds have leaked into groundwater in the vicinity of the Gulf and Shell plants.

Concentrations of metals in the water of the settling ponds were generally very low and mostly within acceptable quality standards for drinking water.

Tentative estimates of sludge volumes in the settling ponds at the two plants suggest that the Shell Waterton plant contains less than half the volume of sludge remaining at the Gulf Pincher Creek plant.

#### **Selenium in Surface Soil at the Gulf Plant Site**

The results of analyzing soil from three places on the Gulf site (Table IV-8) show that soil whose pH had been severely depressed by contamination with oxidized sulphur had considerably more total selenium than uncontaminated soil.



In view of this result, it seems unlikely that soil acidification caused by oxidation of wind-blown elemental sulphur would depress selenium uptake by vegetation and thereby induce selenium deficiency in grazing animals.



## **CHAPTER FOUR**

### **GASEOUS AND PARTICULATE EMISSIONS**

Chapter Five of the main report relates to surface migration from the Gulf Pincher Creek and Shell Waterton plants through gaseous and particulate emissions leaving the incinerator and flare stacks as well as particulate and gaseous matter carried by the wind from above the plant site to the neighbouring lands. To gain the necessary background for the study, the reports of several other studies pertinent to this phase of the work were examined to assist in the formulation of a program of work and to check on other identified matters of concern.



## EMISSIONS FROM THE INCINERATOR

The report by the University of Windsor group on trace element emissions from stacks indicated that aluminum, copper, iron, titanium and zinc were lost from the plant system in amounts ranging from 1.3 to 140 g/h (grams per hour) from the incinerator stacks of the plants. Analyses of the soil and dust in the vicinity of the air blowers of the Claus unit at each plant suggest that these metals probably came from the soil and dust picked up by the winds and carried through the reaction system to the incinerator. The amounts of these elements likely to be ingested from the air by people living in the area are reported to be negligibly small compared with the estimated daily intake from food sources.

In view of the relatively long reaction time, the excess of oxygen and the high temperatures throughout the incinerator stacks, it was considered that any residual organic compounds in the waste gases sent to the incinerator would be combusted completely, forming carbon dioxide and water. It was learned from Shell that through its own investigations the presence of carbonyl sulfide at concentrations of a few parts per million were found in the incinerator stack effluent along with the residual sulfur dioxide from the Claus process. It is possible that this carbonyl sulfide was responsible in part for the odour sometimes detected downwind from the plant. In view of the work done by the Windsor Group and Shell on components being emitted by the incinerator stack, the Task Force decided not to pursue these studies further.



## EMISSIONS FROM FLARE STACKS

Reports by M. T. Strosher of the Kananaskis Centre for Environmental Research and by Sciex indicated the presence of trace organic compounds in the air downwind from the plant. For this reason, additional studies were made using the "Tenax" adsorbent technique to collect heavier components in the air so that they could be later analyzed by a GC/MS instrument at the Kananaskis Centre. At the same time analyses were made with a trace sulphur gas analyzer. Samples were taken of the air at various points downwind and upwind from the plant as well as of the gas leaving the flare stack of plant No. 2 while gases from various points in the process were being vented to this flare. The results of the GC/MS analyses done downwind from the plant show a remarkable correspondence in the compounds identified when compared with samples obtained from the flare. The presence in the ambient air of compounds such as phenol and styrene which are not present in the raw gas is considered good evidence that the organic components detected result from incomplete combustion in the flare. This incomplete combustion will contribute to the odour problem downwind due to the presence of unburned hydrogen sulphide and other sulphur containing compounds in the effluent.

The correspondence between the compounds detected in the air and those present in condensate suggests that gas being flared contains volatile components of condensate. Condensate for the most part should be trapped in the "knock out" drum immediately upstream from the flare stacks. Gases being flared, however, on passage through the "knock out" drum will carry some of these volatile components to the flare.



## AMBIENT AIR QUALITY

Several compounds identified in the samples collected from the air downwind from the plant are known to be toxic and at least one such compound, benzene, is a known carcinogen (benzene and several of the toxic materials are components of gasoline). Assuming incomplete combustion under adverse flaring and dispersion conditions, the concentrations of toxic materials such as sulphur dioxide, hydrogen sulphide, benzene and phenol may increase in the atmosphere for varying periods of time, depending on weather conditions, wind speed and direction during the flaring, and the material being flared. Whether the concentrations could increase sufficiently to cause problems for certain sensitive people is not known.

While threshold limit values have been set for these substances when present in a workroom environment, safe levels for the open air have not been set. Judging by the quantitative estimates made by the Kananaskis Centre for Environmental Research in a survey of the ambient air in the vicinity of the two plants in 1981, none of the components detected was found to be at concentrations considered serious to health when judged by workplace standards. However, the residents of the area may be subjected to the emissions for longer periods than industrial workers in the workplace. Some members of the residential population also may be in a much poorer state of health than industrial workers or may be more delicate as are children and hence susceptible to the effects of toxic materials at considerably lower concentrations.



The effect of sulphur dioxide alone in the atmosphere at levels between 0.25 and 0.40 ppm has recently been reported to cause increases in airway resistance of some asthmatics undergoing exercise for periods of 5 to 10 minutes. The effects of traces of sulphur dioxide and hydrogen sulphide in combination with the traces of organic compounds found present in the air might be more severe than those of the individual compounds in isolation. Suitable well-controlled clinical tests of sensitive people in the area might possibly establish whether or not the effluents leaving the incinerator flare stacks are in any way responsible for some of the health problems about which some of the residents complain.

Based on the analysis of the air downwind from the Shell plant and on analyses of the combustion gases from the flare, there is sufficient evidence to recommend that the operation of the flare stacks be reviewed. It is further recommended that efforts be made to ensure that combustion of the waste gases sent to the flare is as complete as is technically feasible. Efforts should be made to prevent condensate from accumulating in the knock-out drum upstream from the flare.



## **CHAPTER FIVE**

### **CONCLUSIONS**

This chapter summarizes the main conclusions agreed to by the Task Force regarding air, soil and water quality in the Twin Butte area.

#### **GENERAL CONCLUSIONS**

In reviewing the overall impact of air, soil and water quality in the Twin Butte area, the Task Force has concluded that:

1. Based on the analytical evidence available, (Monenco Report) toxic materials are present in the ponds, in landfills and in areas actively used during the Gulf plant operations. The Task Force study indicates that, with minor exceptions, these substances are contained within the boundaries of this plant site.



2. Preliminary reconnaissance conducted by the Task Force at the Shell plant site identified the presence of sulpholane and a compound of formula  $C_7H_{11}NO_3$  in the groundwater. Sludges in the tested ponds did not contain substantial quantities of trace metals. No soil survey at this plant was conducted.
3. No evidence was found that heavy metals or toxic substances in substantive quantity, originating from gas processing, have migrated from the plant sites. The exceptions to this statement were:
  - Mercury levels at piezometer (29-1) at the Gulf Pincher Creek plant were observed to be slightly higher than background levels.
  - Arsenic levels exceeding drinking water standards were identified in early 1983 at the discharge point from the Shell Waterton plant into the Drywood Creek.

## SURFACE WATER AND GROUNDWATER HYDROLOGY

The impact of the Shell Waterton and Gulf Pincher Creek gas plants on water quality in the Twin Butte area have been reviewed thoroughly. The Task Force has concluded that:

1. The quality of effluent from the two plants generally complied with the Process Effluent Standards established by Alberta Environment. Occasional contraventions of these standards were observed in the past. Effluent from the Shell Waterton Gas Plant causes an increase in total



dissolved solids, main ions, nutrients and some trace element concentrations in the North Drywood Creek and Drywood Creek. The Gulf Pincher Creek Gas Plant has ceased operation; however, it is reasonable to conclude that, in the past, effluent discharge from the Gulf plant had similar downstream effects to those observed at the Shell plant.

With the exception of North Drywood Creek and Drywood Creek, no other creeks or lakes in the area have water quality distinctly affected by the Shell and Gulf plant operations.

2. The environmental isotope studies indicate that the surface water system is hydraulically continuous with the shallow groundwater system and that recharge is rapid in geological terms. Available results indicate that there is no evidence that groundwater quality is affected by  $\text{SO}_2$  and  $\text{H}_2\text{S}$  emitted from the gas plants.
3. Groundwater quality in the wells located in the areas adjacent to the Shell and Gulf plants does not indicate the presence of anomalies which could be attributed to industrial pollution. The only exceptions to this statement are the anomalously high values of total dissolved solids and sulphates in the area extending SE of Gulf's Pond 8 and in the spring water below the Shell plant in the North Drywood Creek Valley.



4. Localized zones of groundwater contamination are present at the Shell Waterton and Gulf Pincher Creek plants. High total dissolved solids and sulphate concentrations are prime indications of groundwater contamination. At the Gulf plant, anomalous concentrations of trace elements and organic compounds, which could be attributed to the plant operation, were detected. Sulpholane, an essentially non-toxic chemical used in sour gas processing, was found in concentrations up to 100 ppm in groundwater at the Shell Waterton plant.
5. The most important observations based upon the geochemical weathering tests of six till samples from the Twin Butte area are:
  - a) that a threshold partial pressure exists below which there is little or no reaction of  $\text{SO}_2$  with an aqueous suspension of soil/till, and
  - b) that the release of trace metals can occur only if the pH of the soil-water system falls below a pH value of 3.0 approximately. The threshold value of the partial pressure of  $\text{SO}_2$  corresponds to a concentration between 34 mg/L and 3400 mg/L for the materials studied. Increasing amounts of organic carbon, calcium, sulfate, silica, copper, lead, cadmium, cobalt, nickel, manganese, vanadium, chromium, strontium, aluminium, and zinc were released upon exposure of a shallow till sample to 3400 mg/L of sulphur dioxide. The trace metals released were not at toxic levels, even at a pH as low as 2.4.



## ANALYSIS OF SOIL AND VEGETATION

The Task Force has reviewed the data and concludes that:

1. Sulphur, presumably as  $\text{SO}_2$ , has been air borne in the direction of a) the Drywood Creek valley at least as far as the Waterton reservoir, b) the Pincher Creek valley as far as Daigle Lake and possibly c) the Foothill Creek valley as far as Rouleau Lake.
2. There has been no detectable increase in acidity or electrical conductivity of soil, litter and lake sediment in these areas, concomitant with the readily detectable increase in  $^{34}\text{S}$  which has resulted from operation of the gas plants.
3. Equally, there has been no detectable, concomitant increase in concentrations of metals in soil, vegetation or lake sediment in these areas.
4. There was no indication of any increase in concentrations of metals in potatoes and carrots grown in 1983 in the study area, as a result of gas plant operations. The vegetables obtained were safe to eat.
5. There were indications of contamination with chromium, lead and zinc in bullrushes downslope from settling ponds at the Gulf Pincher Creek plant, possibly because of surface run-off.



## GASEOUS AND PARTICULATE EMISSIONS

The Task Force has reviewed the data and concludes that:

1. The organic compounds detected in trace amounts in the ambient air were a result of flare stack emissions.
2. Gases directed to the flare stack during the tests contacted condensate, a volatile liquid fraction produced from the raw gas, which was trapped in the knock-out drum immediately upstream from the flare.
3. Condensate may be carried into the flare when gases from various points in the plants are flared. Combustion of this condensate was incomplete, under the conditions of the tests undertaken, giving rise to the presence of the organic compounds detected in the ambient air downwind from the plant.
4. The trace element emissions from the incinerator stack detected by the University of Windsor Group probably came from the soil and dust picked up by the wind and then carried through the reaction system.
5. The Shell plant finds it necessary to add sweet gas to sour gas when the latter is being flared to achieve greater thermal lift and to decrease concentrations of sulphur dioxide at ground level to values less than the standards set for ambient air quality. It is therefore concluded that when flaring



occurs, the sulphur dioxide levels downwind from the flare stack will tend to approach the upper limits of the standard. Insufficient dilution of the sour gas with sweet gas, coupled with adverse dispersion conditions, could cause ambient sulphur dioxide levels to exceed the standard for short periods.



## **CHAPTER SIX**

### **RECOMMENDATIONS**

This chapter summarizes the recommendations which have been made following detailed review of findings and conclusions regarding air, soil and water quality in the Twin Butte area.

#### **SURFACE WATER AND GROUNDWATER HYDROLOGY**

The Task Force recommends that:

1. A further survey of groundwater and surface water should be conducted to determine the presence and concentrations of organic compounds near the Shell Waterton plant. This recommendation follows from the detection of sulpholane in shallow groundwater on the



Shell plant site, and also accommodates the possibility of air-borne contamination of surface water. Groundwater samples should be subjected to a standard fish toxicity test.

2. The monitoring of surface water, spring and observation wells at the Shell Waterton plant should be continued. Additional piezometer nests should be added in the areas of Basin A, Plant #2 Slurry pond and Basin K. A detailed survey of the solid waste disposal sites should be conducted and an appropriate groundwater monitoring system established.
3. The reclamation program developed by Gulf should be implemented and progress of the work monitored by the owner and by government agencies. Since the Pincher Creek plant was the first major sour gas plant built and the first to be closed in Alberta, the experience gained in the site reclamation should be used to establish appropriate guidelines for operating and decommissioning similar plants. Additional piezometers should be installed and isotope studies conducted to define the origin of the hydrochemical anomalies SE of Pond 8 in the upper and lower aquifers. Piezometer 29-1 should be resampled and mercury concentrations in the groundwater confirmed. Groundwater samples should also be monitored for contamination by organic compounds.
4. Detailed hydrological and hydrogeological studies (including application of environmental isotopes) should be conducted, prior to any new sour gas plant construction. This would provide hydrochemical base-line data, which may be required in the future for environmental impact assessments.



5. Procedures for water sampling, preservation and transportation to be used in all hydrochemical studies should be established. Analytical methods for different ions or compounds should be recommended. Present use of methods with different levels of accuracy make evaluation and comparison of the results very difficult.
6. The results of the artificial weathering tests in the SO<sub>2</sub> atmosphere indicate great potential for this method in future studies related to sour gas plant operations. Further studies should be conducted to define the sensitivity of different soils in Alberta to sulphur loading and release of trace elements. This study should also include an evaluation of the potential impact on groundwater quality of the effects of deposition of sulphur dust on the ground surface.

## ANALYSIS OF SOIL, VEGETATION AND SEDIMENT

The Task Force recommends that:

1. After an appropriate time interval (5 years?) measurements of  $\delta^{34}\text{S}$  values in soils, vegetation and lake sediments should be repeated to establish whether an equilibrium has been reached or whether  $\delta^{34}\text{S}$  values are still increasing to more positive levels. This may indicate whether potentially damaging effects of airborne sulphur deposition have reached a plateau. A more detailed



sampling would also confirm whether this airborne sulphur actually follows the valleys of the Drywood, Pincher and Foothill Creeks.

## **GASEOUS AND PARTICULATE EMISSIONS**

The Task Force recommends that:

1. The placement, design and operation of the flare stacks should be reviewed and efforts made to ensure the most complete combustion, that is technically feasible, of the waste gases sent to flare stacks.
2. The condensate trapped in the knock-out drum immediately upstream from the flare stack should be kept at a minimum level so that gases being flared carry as little condensate as possible to the flare.
3. Plant operating procedures should be reviewed with the objective of eliminating the need for, or reducing the extent of, flaring within technically feasible limits.
4. In addition to monitoring the ambient air for sulphur dioxide and hydrogen sulphide, analyses should be made when flaring is taking place to determine whether the concentrations of organic compounds in the ambient air downwind from the plant reach levels which might be considered hazardous.



5. Future studies of the effects on animal health of compounds added to inhaled air should include the organic compounds found in ambient air near the Shell plant as well as sulphur compounds such as  $\text{SO}_2$ ,  $\text{H}_2\text{S}$ ,  $\text{CS}_2$  and  $\text{COS}$ .

#### **GENERAL RECOMMENDATION**

The Task Force recommends that:

1. The operators of these and other sour gas plants should continue to maintain a close liaison with residents of local communities through such things as joint committees, newsletters, etc., to avoid misunderstanding and animosity that compromise efforts to achieve an objective appraisal of the effects of sour gas processing.





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